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Conversion of xylan, D-xylose and lignocellulosic biomass into furfural using $AlCl_3$ as catalyst in ionic liquid

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HIGHLIGHTS

- ▶ $AlCl_3$ was used as catalyst in ionic liquid to produce FUR from xylan and xylose firstly.
- ▶ $AlCl_3$ was more effective than mineral acid in producing FUR from xylan in ionic liquid.
- ▶ The treatments were conducted at atmospheric pressure.
- ▶ The catalyst was cheap and easily available.
- ▶ The catalytic system was more ecologically viable than current technology.

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ABSTRACT

In order to define a new green catalytic pathway for the production of furfural, the catalyzed conversion of xylan into furfural in 1-butyl-3-methylimidazolium chloride was studied by using mineral acids and metal chlorides as catalysts under microwave irradiation. Amongst these catalysts, $AlCl_3$ resulted in the highest furfural yield of 84.8% at 170 °C for 10 s. The effect of $AlCl_3$ on the conversion efficiency of D-xylose and untreated lignocellulosic biomass was also investigated, the yields of furfural from corncob, grass and pine wood catalyzed by $AlCl_3$ in [BMIM]Cl were in the range of 16–33%. [BMIM]Cl and $AlCl_3$ could be recycled for four runs with stable catalytic activity. $AlCl_3$ is less corrosive than mineral acids, and the use of ionic liquid as reaction medium will no longer generate toxic wastewater, thus this reaction system is more ecologically viable.

1. Introduction

Furfural is a highly versatile and key derivative used in the manufacture of a wide range of important chemicals, and it is likely to be of increasing demand in different fields, such as oil refining, plastics, pharmaceutical, and agrochemical industries (Dias et al., 2006). Besides, furfural and its derivatives have been used to make jet and diesel fuel range alkanes, to serve as a gasoline blendstock, and to develop new generation of biofuels and bioplastics (Xing et al., 2011). There is no synthetic route for the production of furfural, furfural is industrially synthesized from lignocellulosic materials (corncobs, oat hulls, cottonseed hull bran, almond husks, and bagasse etc.) that are rich in pentosans in either batch or continuous reactor using mineral acids (H_2SO_4 or HCl) as catalyst. Superheated steam is also used as the stripping agent to remove furfural from the reacting medium simultaneously to minimize loss, but this process consumes energy hugely. Drawbacks are inevitable in inorganic acid catalyzed processes, in short, the conventional process for producing furfural costs a lot, suffers from equipment corrosion, and results in huge amounts of toxic effluents. Environmental concerns, safety issues, energy costs, as well as waste-disposal problems are among the main reasons why furfural production in EU and USA has been strongly hampered in the last few decades (Marcotullio and De Jong, 2010). Hence, novel eco-friendly catalytic processes for furfural production are badly needed in order to approach the same yields under significantly milder conditions to minimize the carbon footprint (Mamman et al., 2008).

Recent furfural manufacturing-process optimization investigations involving the use of either homogeneous acids (Rong et al., 2012; Yemis and Mazza, 2011) or heterogeneous solid acids (Rinaldi and Schuth, 2009; Agirrezabal-Telleria et al., 2012; Lima et al., 2008; Agirrezabal-Telleria et al., 2011) as catalysts by monophasic (Marcotullio and De Jong, 2011; Chareonlimkun et al., 2010) or biphasic system (Weingarten et al., 2010; Lessard et al., 2010). Xing

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